DECLARRATION

I, Atsushi ONOGI, the translator of the attached document, do hereby certify that to the best of my knowledge and belief the attached document is a true English translation of Japanese Patent Applications Nos. 2001-53390 and 2001-86813.

Signed, this 19th day of March, 2004

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Date of Filing: March 26, 2001
Japanese Patent Application No.: 2001-86813

[Name of Document]	Application for Patent
[Reference No.]	0102352
[Date of Filing]	February 28, 2001
[Addressee]	Commissioner of Japan Patent Office
[Int'l Class]	G11B 7/00
[Title of the Invention]	Information recording method, Information playback method, information recording and playback method, and phase change recording medium
[Number of Claims]	10
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[Application Fee]

[Prepayment No.] 063027

[Amount of Payment] 21,000 Yen

[List of Attached Documents]

[Name of Document] Specification 1

[Name of Document] Drawings 1

[Name of Document] Abstract 1

[General Power of Attorney] 9808802

[General Power of Attorney] 0004335

[Necessity of Proof] Necessary

[Name of Document] Specification

[Title of the Invention] Information recording method, Information playback method, information recording and playback method, and phase change recording medium

[Scope of Claims]

[Claim 1] An information recording method of recording multi-leveled information in a phase change information recording medium, comprising:

forming recording marks in the recording medium by irradiating a record/playback light beam thereon, while changing a mark length of the recording marks in a disc tangential direction at a cycle of 0.5 to 1.0 time of a beam diameter of the recording/playback beam, to record the multi-leveled information, wherein the beam diameter is 1/e2 of a peak value of the light beam.

[Claim 2] The information recording method according to Claim 1, wherein, using a recording pulse strategy modulating a power level to at least two levels, the mark length is varied by changing at least

one power level depending on information recorded in the medium.

[Claim 3] The information recording method according to Claim 1, wherein, using a recording pulse strategy modulating a power level to at least two levels, the mark length is varied by changing a time for holding at least one power level depending on information recorded in the medium.

[Claim 4] The information recording method according to Claim 1, wherein, using a recording pulse strategy modulating a power level to at least two levels, the mark length is varied by independently changing at least one power level and a time for holding at least one power level depending on information recorded in the medium.

[Claim 5] The information recording method according to Claim 2 or 4, wherein the modulated power levels are three levels of a recording level, an erasing level which is lower than the recording level, and a bias level which is lower than the erasing level, and the power level changed depending on information recorded in the medium is the erasing level.

[Claim 6] The information recording method according to Claim 3 or 4, wherein the modulated power levels are three levels of a recording level, an erasing level which is lower than the recording level and a bias level which is lower than the erasing level, and the power level, the holding time of which is changed depending on the information recorded in the medium, is at least one of the recording level and the bias level.

[Claim 7] A phase change recording medium, comprising:

a recording layer in which recording information is recorded as multi-leveled information by the information recording method of Claim 1 or 6.

[Claim 8] The phase change recording medium according to Claim 7, wherein the recording layer comprises:

Sb, Te and at least one element selected from the group consisting of Ag, In, Ge, Ga, B, Si and Al, wherein a ratio of Sb to Te is from 2 to 5.

[Claim 9] An information playback method of playing back multi-leveled information in the phase change recording medium of Claim 7 or 8, comprising:

playing back the multi-leveled information by detecting changes in an amount of reflected light depending on the changes of the mark length.

[Claim 10] An information recording and playback method of recording and playing back multi-leveled information in a phase change recording medium, comprising:

forming record marks in the recording medium by irradiating a recording/playback light beam thereon, while changing a mark length of the recording marks in a disc tangential direction at a cycle of 0.5 to 1.0 time of a beam diameter of the recording/playback beam, to record the multi-leveled information, wherein the beam diameter is 1/e2 of a peak value of the light beam; and

playing back the multi-leveled information by detecting changes in an amount of reflected light depending on the changes of the mark length.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to an information recording method intended for high density recording by multi-leveled information recording, an information playback method, an information recording and playback method and a phase change recording medium.

[0002]

[Background Art]

Among optical recording media for recording and playing back information using a laser beam, there is a rewritable phase change recording medium using a phase change material for the recording layer thereof. This phase change recording medium uses a material for the recording layer which reversibly changes between an amorphous state and a crystalline state upon irradiation of light. The phase change

recording medium can record and erase information by a simple optical system, and in addition, can easily record new information while erasing recorded information.

[0003]

In recording methods using such phase changes, typically a two-valued information recording, i.e., whether a recording mark exists or not, is used. However, a multi-leveled information recording, in which multiple pieces of information can be recorded in one recording unit, has been devised for high density recording and high-speed data transfer.

[0004] Published unexamined Japanese Patent Applications Nos. 8-287468 and 11-25456 disclose a method of changing an area, shape or structure of recording pits to have multiple average reflective indices and a method of defining multiple combinations of positions and allocations of recording marks.

[0005]

[Problems to be Solved]

It is necessary to reduce the size of one recording unit to increase a recording density by a multi-leveled information recording. In addition, it is also important to have a large dynamic range for reflectivity variance in the small unit. Further, complicated recording pulse strategies need to be avoided in terms of recording speed and cost of a drive.

[0006]

Considering theses points, conventional multi-leveled information recording methods disclosed in published unexamined Japanese Patent Applications Nos. 8-287468 and 11-25456 mentioned above have problems in that the recording pulse strategy is complicated, etc. Thus the need exists for improvement in the multi-leveled information recording methods.

[0007]

Therefore, it is an object of the present invention to provide an information recording method which can perform a multi-leveled

information recording using a simple recording pulse strategy, an information playback method, an information recording and playback method and a phase change recording medium.

[0008]

[Means for Solving the Problems]

The invention set forth in Claim 1 is an information recording method of recording multi-leveled information in a phase change information recording medium. In this method, recording marks are formed in the recording medium upon irradiation of a record/playback light beam thereon, while the mark length of the recording marks in a disc tangential direction is varied at a cycle of 0.5 to 1.0 time of a beam diameter of the recording/playback beam to record the multi-leveled information. The beam diameter is 1/e2 of a peak value of the light beam.

[0009] Therefore, since the mark length in the phase change recording medium changes, a ratio of a area in amorphous state to that in crystalline state as a base varies. Therefore, multi-leveled information can be recorded by varying a mark length, which is not greater than the beam diameter of the recording/playback beam, to multi-leveled mark lengths at a predetermined cycle in relation to the beam diameter of the recording/playback beam. In addition, the recording pulse strategy used can be simple.

[0010]

The invention set forth in Claim 2 is the information recording method according to Claim 1 in which, using a recording pulse strategy modulating a power level to at least two levels, the mark length is varied by changing at least one power level depending on information recorded in the medium.

[0011]

Therefore, it is possible to vary a mark length to multi-leveled mark lengths in the dimension which is not greater than the beam diameter by a simple recording pulse strategy in which at least one power level is varied.

[0012]

The invention set forth in Claim 3 is the information recording method according to Claim 1 in which, using a recording pulse strategy modulating a power level to at least two levels, the mark length is varied by changing a time for holding at least one power level depending on information recorded in the medium.

[0013]

Therefore, it is possible to vary a mark length to multi-leveled mark lengths in the dimension which is not greater than the beam diameter by a simple recording pulse strategy in which a time for holding at least power level is varied.

[0014]

The invention set forth in Claim 4 is the information recording method according to Claim 1 in which, using a recording pulse strategy modulating a power level to at least two levels, the mark length is varied by independently changing at least one power level and a time for holding at least one power level depending on information recorded in the medium.

[0015]

Therefore, it is possible to finely vary a mark length to multi-leveled mark lengths by independently varying at least one power level and a time for holding at least power level are independently varied.

[0016]

The invention set forth in Claim 5 is the information recording method according to Claim 2 or 4 in which, the modulated power levels are three levels of a recording level, an erasing level which is lower than the recording level, and a bias level which is lower than the erasing level, and the power level changed depending on information recorded in the medium is the erasing level.

[0017]

Therefore, when the power level is modulated into three levels, it is possible to vary a mark length to multi-leveled mark lengths

in the dimension which is not greater than the beam diameter by changing the erasing level using a simple recording pulse strategy.

[0018]

The invention set forth in Claim 6 is the information recording method according to Claim 3 or 4, wherein the modulated power levels are three levels of a recording level, an erasing level which is lower than the recording level and a bias level which is lower than the erasing level, and the power level, the holding time of which is changed depending on the information recorded in the medium, is at least one of the recording level and the bias level.

[0019]

Therefore, when the power level is modulated into three levels, it is possible to vary a mark length to multi-leveled mark lengths in the dimension which is not greater than the beam diameter by changing the time for holding at least one of the recording level and the bias level using a simple recording pulse strategy. It is preferable to change the time for holding both the recording level and the bias level.

[0020]

The phase change recording medium of the present invention set forth in Claim 7 includes a recording layer in which information is recorded as multi-leveled information according to the information recording method set forth in Claim 1 or 6.

[0021]

Therefore, it is possible to provide a phase change recording medium in which high density recording is performed using a simple recording pulse strategy.

[0022]

The invention set forth in Claim 8 is the phase change recording medium according to Claim 7, in which the recording layer contains Sb, Te and at least one element selected from the group consisting of Ag, In, Ge, Ga, B, Si and Al and the ratio of Sb to Te is from 2 to 5.

[0023]

Therefore, by having such a recording layer structure, the crystallization speed is high and in addition strongly depends on the laser power. That is, phase change reaction to the recording pulse is fast. This is preferable for the information recording method set forth in Claim 1 or 6, the information playback method set forth in Claim 9 and the information recording and playback method set froth in Claim 10.

[0024]

The invention set forth in Claim 9 is an information playback method which playbacks multi-leveled information in the phase change recording medium set forth in Claim 7 or 8. The multi-leveled information is played back by detecting changes in the amount of reflected light caused by the change of the mark length.

[0025]

Therefore, in the case of phase change recording media, when a mark pitch is not greater than the diffraction limit of the playback beam, the amplitude lowers. Therefore, it is possible to vary the intensity of reflected light to multiple levels according to the ratio of the area of amorphous state to that of crystalline state as a base. Thus, with regard to multi-leveled information recorded corresponding to the mark lengths varied within a predetermined cycle depending on information recorded as set forth in Claim 1 or 6, it is possible to play back multi-leveled information by detecting changes in intensity of the reflected light.

[0026]

The invention set forth in Claim 10 is an information recording and playback method of recording and playing back multi-leveled information in a phase change recording medium. In this method, recording marks are formed in the recording medium upon irradiation of a recording/playback light beam thereon, while the mark length of the recording mark in a disc tangential direction is changed at a cycle of 0.5 to 1.0 time of a beam diameter of the recording/playback beam, to record the multi-leveled information. The beam diameter is 1/e2

of a peak value of the light beam. The multi-leveled information is played back by detecting changes in an amount of reflected light depending on the change of the mark length.

Therefore, since the ratio of the area in the amorphous state and that in the crystalline state as a base changes according to changes of the mark length in phase change recording media, it is possible to record multi-leveled information by varying the mark length to multiple levels not greater than the diameter of the recording and playback beam with a predetermined cycle in relation to the diameter. In addition, the recording pulse strategy used therefor can be simple.

Further, in the case of phase change recording media, when a mark pitch is not greater than the diffraction limit of the playback beam, the amplitude lowers. Therefore, it is possible to vary the intensity of reflected light in multiple levels according to the ratio of the area in the amorphous state to that in the crystalline state as a base. Thus, with regard to multi-leveled information recorded corresponding to the mark lengths varied within a predetermined cycle depending on information recorded as mentioned above, it is possible to play back multi-leveled information by detecting changes in intensity of the reflected light.

[0028]

[Description of the Preferred Embodiments]

An embodiment of the present invention will be described with reference to Figs.1 and 2.

[0029]

Fig.1 is a schematic diagram illustrating the embodiment of the information recording and playback method. Fig.1(a) illustrates the beam shape of a recording/playback beam B and the phase change mark shape in the phase change recording medium.

[0030]

A mark M is formed in one unit U, i.e., a recording unit. In the information recording method for use in this embodiment, basically a length in the tangential direction, i.e., a mark length, of the mark

M is varied to multiple lengths depending on information recorded. When the mark length changes, the ratio of the area in the amorphous state and that in the crystalline state as a base in one unit varies. In this embodiment, a length L of the unit U is from 0.5 to 1.0 time the beam diameter Φ represented by 1/e2, and preferably from 0.75 to 0.9 times. The mark M is formed by a constant cycle P corresponding to the unit length L.

[0031]

When a mark pitch is not greater than the diffraction limit of the playback beam B, the amplitude lowers. Therefore, it is possible to vary the intensity of reflected light to multiple levels according to the ratio of the area in the amorphous state to that in the crystalline state as a base. Thus, in this embodiment, multi-leveled information is recorded by varying the mark length in the unit U to multi-leveled mark lengths depending on information recorded. In addition, the multi-leveled information is played back by detecting changes in the amount of the reflected light.

[0032]

The method of controlling the mark length to the dimension which is not greater than the beam diameter Φ will be described next. The power level of the laser power is modulated into two levels and preferably into more than two levels. Fig.1(b) illustrates the recording pulse strategy of this embodiment and the power level is modulated into three levels using rectangular waves. The laser power is modulated into a recording power level Pw, a bias level Pb and an erasing level Pe in this order to form a mark M in each unit U, wherein the following relationships are satisfied: Pw > Pe > Pb.

[0033]

In Fig.1, a portion (I) illustrates an example of controlling a mark length in which at least one power level, preferably the erasing level Pe, is varied depending on information recorded. By varying this erasing level Pe, it is possible to change the timing of erasing the end portion Me of the mark M. When the erasing level Pe is lowered

as in the case of Pe1, the crystalline speed decreases and the erasing timing is delayed. Therefore, the mark length of the mark M recorded is long. When the erasing level Pe is raised as in the case of Pe3, the crystalline speed becomes high and the timing of erasure is close to the shape of irradiation wave. Therefore, the mark length of the mark M recorded is short. By varying the erasing level Pe to multiple levels, i.e., Pe1, Pe2 and Pe3, as mentioned above, it is possible to change the mark length in the unit U, i.e., the area occupied by the mark M in the unit U. Specifically, it is preferable to vary the erasing level Pe in the relation to the recording level Pw while satisfying a ratio of Pe to Pw within a range of from 0.0 to 0.7.

[0034]

In Fig.1, a portion (II) illustrates an example for controlling a mark length in which a time for holding at least one power level is varied depending on information recorded. In this example, a holding time Tw for maintaining the recording level Pw, which is equivalent to the pulse width, or a holding time for Tb for maintaining the bias level Pb, is varied to multiple time lengths depending on information recorded. In Fig.1, the portion (II) illustrates a preferable example of varying both holding times, wherein the ratio of these holding times Tw and Tb, i.e., Tw/Tb, are set in the range of from 0.3 to 1.5 are set.

[0035]

The mark M can be shortened by making the holding times Tw and Tb short. To form a long mark M, the holding times Tw and Tb are made to be long. When the holding time Tw is long, the mark M becomes long. When the holding time Tb is long, the cooling time becomes long and thereby the mark ending portion Me is dragged. As a result the mark M becomes further long.

[0036]

In addition, as shown in the examples described later, it is possible to finely control the mark length by independently varying the level of the erasing level Pe, the holding time Tw for the recording

level Pw and the holding time Tb for the bias level Pb.

[0037]

These controlling methods for recording are preferable when a phase change recording medium having a recording layer which is made of a material having the following composition is used. The layer structure of the recording layer is a 4-layer structure typical for a phase change recording medium 1 as illustrated in Fig.2. A recording layer 4 in the phase change recording medium 1 has a characteristic material. The mother components of the recording layer 4 are Sb and Te. The ratio (Sb/Te) of Sb to Te is from 2 to 5, and preferably from 3 to 4. At least one element selected from the group consisting of Ag, In, Ge, Ga, B, Si and Al is added to the SbTe mother layer. Specific preferred examples thereof include AgInSbTe, GeAgInSbTe, GeInSbTe, GeGaSbTe and GaSbTe. When the recording layer 2 has such compositions, the crystalline speed strongly depends on the laser power. In addition, the crystallization speed is high and therefore the phase change reaction to the recording pulse is fast. Therefore the recording layer 2 having such compositions is preferred.

[0038]

[Examples]

Examples based on the embodiments described above will be described.

[0039]

As illustrated in Fig.2, the phase change recording medium 1 has an accumulative layer structure consisting of a polycarbonate substrate 2, a ZnS-SiO2 layer 3, the recording layer 4, a ZnS-SiO2 layer 5, an Ag layer 6 and an overcoat layer 7. The composition of the recording layer 4 is Ge of 3 atomic %, Ga of 7 atomic %, Sb of 65 atomic % and Te of 25 atomic %. The track pitch of the phase change recording medium 1 is 0.4 μm, numeric aperture NA for the optical system thereof is 0.65 and the laser beam used has a wavelength of 405 nm.

[0040]

Fig.3 illustrates the recording conditions for this example and

the measuring results of the mark length. The unit length is 0.5 μm. The length of the mark M in the tangential direction which is recorded at this cycle was measured. The horizontal axis represents the sum of the holding times Tw and Tb and each holding time Tw and Tb is varied. In this example, Tw/Tb = 0.7. The vertical axis represents the mark length and is the measured distance between the front end and the rear end of the mark M on the track center thereof.

[0041]

When the power level ratio Pe/Pw is large, the mark length becomes short. In addition, when the holding timed Tw and Tb are short, the mark length becomes short. States F, E and D illustrated in Fig.3 show changes obtained when the power level ratio Pe/Pw was varied from 0.4 to 0.6 while the time of Tw + Tb was fixed. States C and B show changes obtained when the time of Tw + Tb was varied while the power level ratio Pe/Pw was fixed at 0.6.

[0042]

The mark length of the mark M can be varied to five levels within the range of from 0.1 to 0.4 μm. When a state A where the mark M is not recorded is included, six levels can be set for reflected light in the unit U having a length of 0.5μm.

[0043]

Fig.4 is a diagram illustrating the recording signals and the playback waveform. Fig.4(a) shows a change of the mark shapes (mark length). The unit has a length of 0.5 μm. The states A to F were obtained under each condition described for Fig.3 and recorded with the recording pulse strategy illustrated in Fig.4(b). Fig.4(c) illustrates a playback waveform of the phase change recording medium 1 in which the mark Ms are recorded in this way. The vertical axis represents changes of the intensity of reflected light. The intensity of the reflected light changes following a staircase pattern due to the interference between the marks. The area occupied by the amorphous mark changes and thereby the intensity level changes.

[0044]

By using the recording pulse strategy as illustrated in Fig.4(b) and recording in the recording layer 4 having the compositions mentioned above, the number of the reflected light levels can be six with a simple and single recording pulse strategy. That is, it is possible to record and play back 6-leveled information.

[0045]

[Effects of the Invention]

According to the information recording method of the present invention set forth in Claim 1, in the case of a phase change recording medium, the ratio of the area occupied by the amorphous mark to that by the crystalline state as a base varies depending on changes of the mark length. Therefore, multi-leveled information can be recorded in the phase change recording medium by varying the mark length which is not greater than the beam diameter to multi-leveled mark lengths at a predetermined cycle in the relation to the recording/playback beam diameter. In addition, the recording pulse strategy used for the recording method can be simple.

[0046]

According to the present invention set forth in Claim 2, in the information recording method set forth in Claim 1, with regard to the recording pulse strategy modulating a power level to at least two levels, a simple recording pulse strategy in which at least one power level is changed can vary a mark length to multi-leveled mark lengths in the dimension which is not greater than the beam diameter.

[0047]

According to the present invention set forth in Claim 3, in the information recording method set forth in Claim 1, with regard to the recording pulse strategy modulating a power level to at least two levels, a simple recording pulse strategy in which at least a holding time for at least one power level is changed can vary a mark length to multi-leveled mark lengths in the dimension which is not greater than the beam diameter.

[0048]

According to the present invention set forth in Claim 4, in the information recording method set forth in Claim 1, with regard to the recording pulse strategy modulating a power level to at least two levels, the mark length can be finely varied to multi-leveled mark lengths by independently changing at least one power level and a holding time for at least one power level.

[0049]

According to the present invention set forth in Claim 5, in the information recording method set forth in Claim 2 or 4, when the power level is modulated to 3 levels, a simple recording pulse strategy can vary the mark length to multi-leveled mark lengths in the dimension which is not greater than the beam diameter by changing the level of the erasing level.

[0050]

According to the present invention set forth in Claim 6, in the information recording method set forth in Claim 3 or 4, when the power level is modulated to 3 levels, a simple recording pulse strategy can vary the mark length to multi-leveled mark lengths in the dimension which is not greater than the beam diameter by changing the holding time for at least one of the recording level and the bias level.

[0051]

According to the present invention set forth in Claim 7, it is possible to provide a phase change recording medium which can record information with high density using a simple recording pulse strategy.

[0052]

According to the present invention set forth in Claim 8, in the phase change recording medium set forth in Claim 7, by specifying a composition of the recording layer thereof, the crystallization speed is high and is strongly dependent on the laser power. Therefore, the phase change reaction to the recording pulse is fast and thus the phase change recording medium is preferred for the information recording method set forth in Claim 1 or 5, the information playback method set forth in Claim 9 and the information recording and playback method

set forth in Claim 10.

[0053]

According to information playback method of the present invention set forth in Claim 9, in the case of phase change recording media, when a mark pitch is not greater than the diffraction limit of the playback beam, the amplitude lowers. Therefore, it is possible to vary the intensity of reflected light to multiple levels according to the ratio of the area of amorphous state to that of crystalline state as a base. Thus, with regard to multi-leveled information recorded corresponding to the mark lengths varied within a predetermined cycle depending on information recorded as the invention set forth in Claim 1 or 6, it is possible to play back multi-leveled information by detecting changes in intensity of the reflected light.

[0054]

According to information recording and playback method of the present invention set forth in Claim 10, in the case of phase change recording media, since the ratio of the area in the amorphous state and that in the crystalline state as a base changes according to changes of the mark length in phase change recording media, it is possible to record multi-leveled information by varying the mark length to multiple levels not greater than the diameter of the recording and playback beam with a predetermined cycle in relation to the diameter. In addition, the recording pulse strategy used therefor can be simple.

Further, in the case of phase change recording media, when a mark pitch is not greater than the diffraction limit of the playback beam, the amplitude lowers. Therefore, it is possible to vary the intensity of reflected light in multiple levels according to the ratio of the area in the amorphous state to that in the crystalline state as a base. Thus, with regard to multi-leveled information recorded corresponding to the mark lengths varied within a predetermined cycle depending on information recorded as mentioned above, it is possible to play back multi-leveled information by detecting changes in intensity of the reflected light.

[Brief Descriptions of the Drawings]

[Fig.1]

Fig.1 is the example of the present invention illustrating the summary of the information recording and playback method. Fig.1(a) is an explanatory diagram illustrating beam shapes and phase change mark shapes. Fig.(b) is pulse wave form charts illustrating the recording pulse strategy.

[Fig.2]

Fig.2 is a schematic cross sectional diagram illustrating the layer structure of the phase change recording medium.

[Fig.3]

Fig.3 is an explanatory diagram illustrating the recording conditions for the example of the present invention and the measured results for the mark lengths.

[Fig.4]

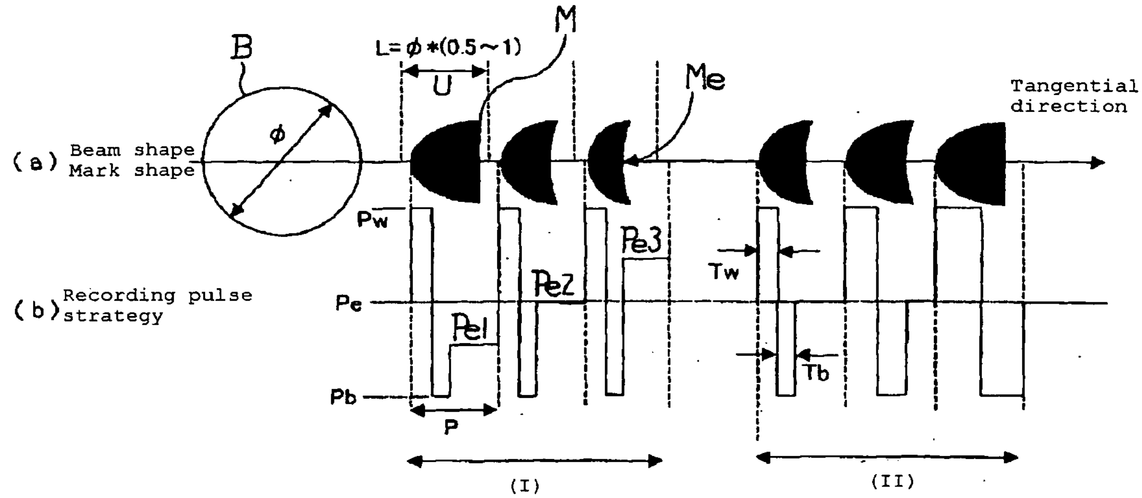
Fig.4 is the example of the present invention illustrating the summary of the information recording and playback method. Fig.4(a) is an explanatory diagram illustrating the phase change mark shapes. Fig.4(b) is a pulse wave form chart illustrating the recording pulse strategy. Fig.4(C) is a wave form chart illustrating the playback wave form.

[Reference Numerals]

1	Phase change recording medium
4	Recording layer
Pw	Recording level
Pe	Erasing level
Pb	Bias level
Tw	Holding time
Tb	Holding time

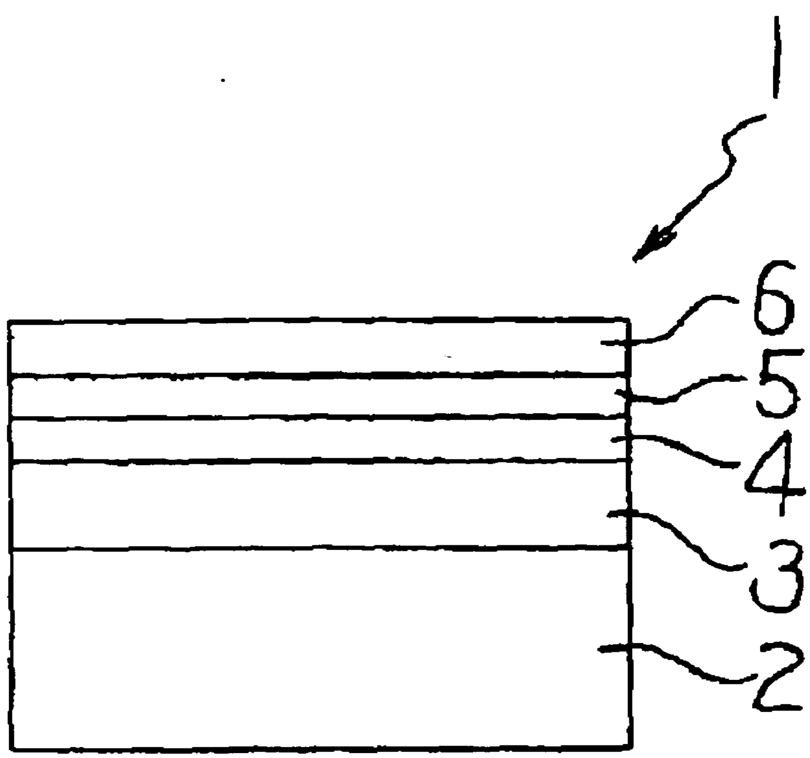
[Name of Document] Drawings

[Fig.1]



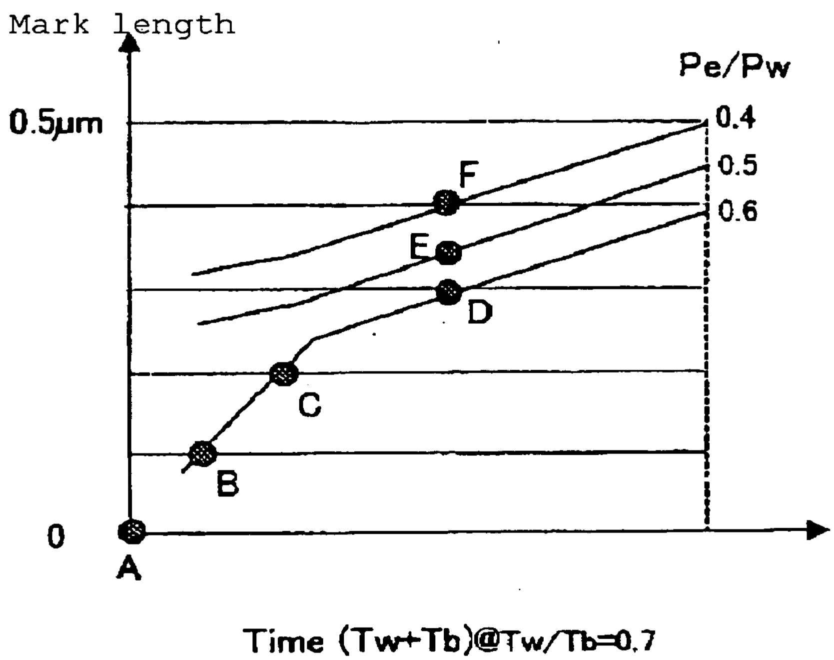
B
L=φ*(0.5~1)
M
U
Me
Tangential direction
(a) Beam shape
Mark shape
φ
Pw
Pe3
Tw
Pe2
(b) Recording pulse strategy
Pe
Pe1
Tb
Pb
P
(I)
(II)

[Fig.2]

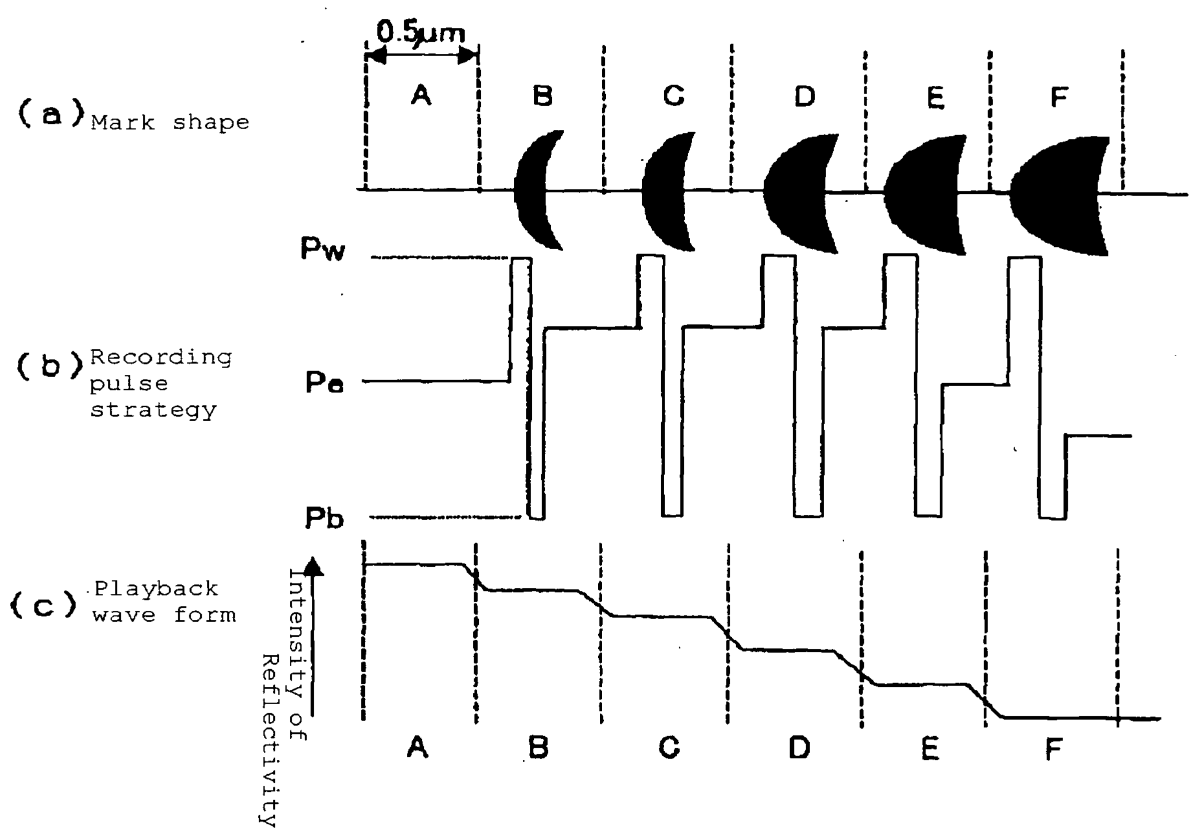


1
6
5
4
3
2

[Fig.3]



[Fig. 4]


0.5μm
A
B
C
D
E
F
(a) Mark shape
Pw
(b) Recording pulse strategy
Pe
Pb
(c) Playback wave form
Intensity of Reflectivity
A
B
C
D
E
F

[Name of Document] Abstract of the Disclosure

[Abstract]

[Object of the Invention] To provide an information recording and playback method by which multi-leveled information recording is performed using a simple recording pulse strategy.

[Means for Solving the Problems] An information recording and playback method for recording and playing back multi-leveled information in a phase change recording medium. The multi-leveled information is recorded by varying a mark length in the disc tangential direction depending on recorded information at a cycle P, which is 0.5 to 1.0 time the recording/playback beam diameter. The recording/playback beam diameter is 1/e2 of the peak value of the recording/playback beam. When the mark length changes, the ratio of the area in the amorphous state to that in the crystalline state as a base also varies. Therefore, multi-leveled information can be recorded by changing the mark length and in addition the recording pulse strategy used can be simple. Further, the intensity of the reflected light varies according to the ratio of the area in the amorphous state to that in the crystalline state as a base so that multi-leveled information can be played back by detecting the change in the amount of the reflected light caused by the change of the mark length.

[Selected Drawing] Fig.1